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Strategies of Teacher Professional Development Focused on Real-World Technology[1] Applications

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Introduction and Objectives

Technology is a fundamental component of most, if not all, businesses and industries. Consequently, classroom students need to engage with technology in ways that better match computer literacy skills and applications in today's workplace (e.g., robotics, computer modeling and simulations, digital animation and multimedia production, biotechnology, and geospatial technologies). These real-world applications offer many benefits for K-12 classrooms including dramatically extending the classroom experience by allowing students to tackle authentic problems and questions, as well as expanding opportunities for teachers to use student-centered inquiries and constructivist practices (e.g., Krajcik et al. 2000, Varma et al. 2008). Various government and privately-funded programs have been developed in response to this need including the National Science Foundation's *Innovative Technology Experiences for Students and Teachers* (ITEST) program, which seeks to increase opportunities for teachers and students to learn about, experience and use science, technology, engineering and math (STEM) in ways that parallel professional applications and promote interest in related careers.

Despite these benefits and opportunities, there is limited research on how best to prepare teachers to incorporate real-world technology applications into their K-12 curriculum. Because they are novel to the classroom, teacher professional development focused on these authentic applications faces unique and significant challenges including considerable time and effort to prepare teachers, as well as schools with insufficient technology resources.

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Our exploratory research study is examining the design of teacher professional development focused on real-world applications of technology; teachers' perception of these experiences; and any subsequent changes in teaching practices. Here we focus on the first phase of our study. Specifically, our research questions are as follows: (1) what strategies are used in teacher professional development focused on real-world technology applications and (2) how do these strategies compare to commonly cited practices of effective professional development.

Theoretical Framework

Many studies have described implementation of technology in elementary and secondary classrooms, and most point to limited applications of these digital tools. For example, in a review of U.S. schools' technology use, Gray et al. (2010) reported that the most common computer-related classroom activities were word processing, spreadsheets, graphing, presentations, Internet searches, and student record management. Similarly, Bebell et al. (2004) surveyed 3,000 teachers and found they primarily used computers for administrative purposes such as class preparation, professional e-mail, and grading. These low-level uses of computers are typically associated with teacher-centered practices (Ertmer et al. 1999) and do not substantially alter a teacher's approach to instruction (Dexter et al. 1999).

To significantly shift teachers' technology use in the classroom, in-service teacher education experiences need to provide opportunities for them to learn, try out, discuss, and refine new practices with these tools. Numerous characteristics or "best practices" of teacher professional development have been reported in the literature. Those repeatedly cited include active learning; opportunities to collaborate with peers and reflect on teaching practices; collective participation (e.g., from the same school or teaching similar subjects); a focus on content knowledge and classroom-based curriculum projects; proximity to classroom practices; differentiated instruction; strong alignment with educational standards; and sufficient time to learn and to implement what has been learned As noted, only a few studies have explored how best to prepare teachers to incorporate real-world technology applications, such as bioinformatics, robotics and digital image analysis, into their K-12 curriculum. In one such study, Varma et al. (2008) found mentoring and coaching during the school day by professional development staff was particularly effective. Other characteristics, such as having teachers working in authentic STEM environments, learning STEM practices, and interacting with STEM professionals, might also be critical to impacting teachers' own learning and their classroom teaching.

To better understand teacher training focused on real-world technology applications and subsequent changes in teaching practices, we are following the recommendation of Penuel et al. (2007) to focus on a specific professional development design. Thus, we are using NSF ITEST "comprehensive" projects as our study group. These teacher professional development projects are ideal because they focused on one or more real-world technology applications and shared a common design (as required by NSF) that was implemented in unique ways.

Methods

To explore these technology-intense teacher professional development projects, we conducted semi-structured phone interviews with leaders from 31 ITEST projects awarded between 2003 and 2008. Project leaders were recruited through an online survey sent to all those funded during this period. We used findings from this survey along with commonly cited professional development practices to develop the project leader interview protocol. We coded the interviews, applying grounded theory by first creating preliminary codes based on responses; we then synthesized the results to determine the most frequent responses.

Results

Among other interview questions, we gave project leaders a list of professional development strategies and asked them to identify which were critical to their project design and why (Table 1). This list was created from our previous project leader survey and from teacher education literature.

Table 1: Professional development strategies that ITEST project leaders were asked to reflect on.

Strategy	Description
Authentic inquires	Professional development activities directly parallel real-world professional STEM activities
Collaboration	Teachers work, in significant ways, with others during the professional development towards a common goal; this includes other teachers, STEM professionals, and youth (in out-of-school experiences that were part of the training)
Collective participation	Project leaders target similar teachers (i.e., same school, grade, subject)
Differentiated instruction	Professional development focuses on customizing activities or materials in response to individual teachers' needs, strengths, or objectives
Focus on a particular pedagogical approach	Professional development highlights a specific pedagogical approach from the literature or best-practices, such as problem-based learning or inquiry
Focus on STEM content knowledge	Professional development focuses on enhancing teachers' STEM content knowledge
Local context	Professional development activities and/or materials are placed within the social and environmental context of local community
Out-of-school experiences	Professional development includes opportunities for teachers to practice new materials and skills with youth outside of the school environment
Proximity to practice	Professional development activities and materials focus on preparing teachers for classroom implementation
STEM career connection	Professional development provide information on STEM career pathways and involved STEM professionals to make direct connections to STEM careers
Teacher as expert	Teachers are treated as pedagogical, content or context experts during the professional development

At least half of the project leaders reported that all but two of these strategies were critical components of their professional development design (Table 2). It should be noted that most of these strategies, such as differentiated instruction, played some role in many ITEST projects but were not necessarily seen as central components of the design and implementation. We reported on three of these strategies in prior publications—collaborations, out-of-school experiences, and authenticity (an integration of authentic inquiries, career connections, and local context) (Stylinski et al. 2011, 2012). Here we examine the other strategies.

Table 2: Percentage of interviewed project leaders who identified the following strategies as critical to their technology-based teacher professional development

Strategy	Percentage of project leaders
Collaborations	97%
Focus on a particular pedagogical approach	91%
Teacher as expert	78%
Out-of-school experience	74%
Authentic inquiries	73%
Proximity to practice	72%
STEM career connections	66%
Local context	53%
Differentiated instruction	53%
Focus on STEM content knowledge	44%
Collective participation	41%

Focus on a particular pedagogical approach

Inquiry-based learning and problem-/project-based learning were the two most frequently mentioned pedagogical approaches (53% and 44%, respectively). Since ITEST projects centered on real-world technology applications within the context of STEM topics, it is not surprising that these approaches were critical components of many professional development designs. As one project leader said, "We really felt the best way to teach science is to teach it as a scientific question and really show how science is a way of knowing." Another explained how they integrated scientific inquiry into their professional development,

> We constructed our activities… all as inquiry activities. For instance, when we were teaching [the teachers] the GIS skills, we gave them a problem to solve that would require at them to look collectively at numerous different layers of data and analyze various associations between data layers to answer the question. We made it a compelling question, like where would you find this type of dinosaur.

Several ITEST project leaders noted that they chose inquiry because it was an efficient way to introduce STEM content and the targeted technology and because it illustrated how technology could be used to expand students' critical-thinking and problem-solving skills. Many remarked that teachers often lack skill in guiding student through this type of active hands-on learning, and thus it was critical for the staff to model ways to support inquiry-, problem-, and project-based learning and for teachers to experience these approaches as learners. One project leader explained,

> We want teachers to see that …when they get to anchor their understanding and prior knowledge, when they are able to negotiate their understanding, when they are able to ask questions that are relevant to them, they are going to learn the content. They are going to be more invested in learning than otherwise.

Another noted that,

> [The] opportunity to experience [an investigative] case as learners, collect their data, come up with an evidence-based conclusion and present that evidence to their peers was a strategy of allowing them to spend time with the content, make sense of the content, and then share whatever their understandings of that case was about.

The other commonly mentioned pedagogical approach was place-based education (13%). This approach aligns well with the strong focus on authenticity, as projects had teachers and students apply real-world digital tools within their local social and environmental context. One project leader noted, "We are really advocating for ethical decision-making, which really highlights a social and environmental impact as related to STEM research and activities." Cultural context was a foundational piece of at least two projects—one working with urban schools and the other set in a Native American community. In the latter, the community actually set the learning priorities for the project, and the students gathered the requested information (e.g., water quality report) and shared their findings with the community.

<u>Teacher as expert</u>

Most, if not all, interviewed ITEST project leaders viewed teacher participants as experts with regard to their local context (72% mentioned it directly). Teachers know the local culture, the school culture, and student culture, as this project leader reported, "[Teacher participants] brought in the knowledge of their students and some of the intangibles--the climate of the school, the support from administration, parental support." Many project leaders also viewed teachers as pedagogical and/or content experts during the professional development (66% and 53%, respectively). Thus, they developed training activities that (1) helped link teachers' existing knowledge to new technology-based content areas such as nanobiotechnology and (2) illustrated how participants could teach existing content using real-world technology applications. As noted, some project leaders felt teachers lack sufficient pedagogical skill with inquiry and other active learning approaches. However, others, especially those led by STEM professionals with little or no classroom experience, had to rely heavily on their teacher participants to serve as pedagogical experts. One such project leader said, "[T]heir expertise was really educating the university folk about what the classroom was like… We are all working together as equal partners…[T]he teachers know how to teach, and we are just trying to give them some tools to help them do it better."

Project leaders also depended on more experienced teachers to formally or informally mentor the novice teachers. As one project leader noted, “The younger teachers are often times willing to try a lot more with the technology then sometimes the teachers that are the thirty years veterans. But, [these veterans] are the ones that actually provide a lot in terms of pedagogical approach.”

Proximity to practice

A majority of ITEST project leaders reported that proximity-to-practice was a critical component of their professional development design and that a close eye to proximity helped ensure the targeted technology was used in the classroom. As this project leader captured, “If they can’t see how it's going to work with their students, they are not going to use it.” Project leaders implemented this by “consciously modeling,” as one leader coined, the pedagogical practice that they were promoting and by leading teachers in regular discussions and reflections on their planned classroom implementation. Many project leaders noted that the out-of-school “youth institute,” which was required by NSF as part of the teacher professional development, provided a key component of this proximity-to-practice strategy. For example, this project leader reported,

> The design of the professional development was really to help teachers step through the curriculum, learn it themselves in a teacher week, and then turnkey it with a small group of guinea pig students during the second week [summer institute], and work through any challenges or bugs or problems, so that when it came time to do it back in their classroom in the fall or spring, they had a thorough understanding of what it would look like and what the issues would be.

This strong alignment to existing curriculum and practice was particularly important because many of the targeted technologies were quite unfamiliar to teachers, as this project leader identified,

> “None of these teachers really had been exposed to game making and game designs. And, if they were going to teach it, they really had to experience it firsthand for themselves what they were going to be doing in the classroom.”

By contrast, some projects purposely detached the professional development activities from common classroom practices. These project leaders wanted to move teachers beyond their existing curriculum, as this one explained, “We want to push the boundaries a little bit and show them that ‘you can do more if you have new tools.’” Others wanted to give teachers a deeper understanding of particular STEM content, skill or related technology by immersing them in real-world STEM practices in ways that did not necessarily transferred directly to the classroom.

Differentiated instruction

Just over half of project leaders reported that customizing professional development activities or materials was a critical element of their professional development design. These leaders provided differentiated instruction through individualized support during group training activities and through classroom visits during implementation. Projects often used technology to provide support including email, blogging, wikis, and other web-based resources. Many noted this type of instruction was very fluid, as described by this project leader, "The daily debriefs helps us communally address things, but most of that differentiated instruction happens on the fly seeing what is going on with the teacher teams [as they work together and sort out problems]."

As with proximity-to-practice, differentiated instruction was quite important because these professional development experiences addressed complex technology applications like GIS, gaming, biotechnology and computer modeling. Many had to provide significant technical assistant; for example, one project had a 3D-model programmer help struggling teachers during their classroom implementation. There were some projects that reported that individualized instruction was not necessary because their projects sought collective participation and thus targeted teachers with very similar needs and requirements.

Focus on STEM content knowledge

Just under half of the ITEST project focused their professional development on specific STEM content knowledge. As noted earlier, many built on teachers existing knowledge to introduce them to unfamiliar content areas such as nanobiotechnology and fiber optics. However, some project leaders found they needed to address basic STEM understanding because their projects attracted a number of English, social studies and other non-STEM teachers. Others found that even their STEM teachers lack sufficient content knowledge, as this project leader described,

> There was huge variation in the content knowledge of the things that we needed the teachers to know before they could get the most out of the workshop….we found quite a few teachers that were uncomfortable with the molecular biology cell and genetic standards.

Overall, there was a tension between improving content knowledge and addressing pedagogical skills related to the targeted technology. One project leader explained,

> We found that…spending too much time on content knowledge is distracting the development of the technological skills that the teachers need to implement effectively in the classroom. And, teachers had expressed a strong desire to focus on the technology rather than the content even though our evaluation results from last year indicated that their content knowledge expanded significantly.

Collective participation

A number of projects recruited teams of teachers from the same school or targeted teachers from similar disciplines to help ensure implementation and to provide a support system during implementation. As this project leader explained,

> [N]ew educational products, resources, applications stand a better chance of being adopted by a school if there are more teachers within schools who are participating….[Also, the] more people who do it and know about it, the more

> people are likely to do it and know about it, just because there is that [critical] mass.

Others remarked that if they had limited enrollment in this way, they would not have filled their challenging professional development program. Some specifically sought a broader diversity of teachers because, as this project leader noted,

> Our goal is to try to get more students into STEM subjects specifically or particularly IT. If we are only looking at the STEM subjects in school or in my case, the programming classes that offered the computer apps, there is a decline in student interested in those classes…We are not going to get more people pursuing STEM by only working with the STEM teachers.

Discussion

Our findings identified multiple shared strategies of teacher professional development focused on real-world technology applications. The most common were collaboration and a focus on a particular pedagogical approach. Teacher as expert, out-of-school experiences, authentic inquiries, proximity-to-practice, STEM career connections, local context, and differentiated instruction were also regularly identified as critical design elements. Less common were focusing on STEM content knowledge and collective participation. Collaboration, out-of-school experience and authenticity (authentic inquiries, STEM career connections, local context) were addressed in our previous papers. Here we focus on project leaders' perspective and approaches with regard to the other six strategies.

Most ITEST projects focused on inquiry, problem-/project-based learning and, to a lesser extent, place-based education. These pedagogical approaches aligned with the emphasis on authentic STEM practices and the local environmental and social context, and they provided an effective way to learn and apply the targeted technology. A number of project leaders felt teachers had insufficient understanding and experience with these approaches (at least in the context of real-world projects), and thus they committed significant time and resources to improving techers' pedagogical skills. Some project also emphasized gains in STEM content knowledge, either by addressing gaps in teachers' basic understanding or extending their foundational knowledge to include new STEM fields.

Despite some gaps in understanding and skills, many project leaders valued the content, pedagogical, and local context knowledge and experience that teachers brought into the professional development. Indeed, in some cases, projects were quite depended on teacher participants' expertise because project staff consisted of STEM professionals with little teaching experience. This emphasis on teachers as experts matches our earlier finding that projects promote collaborations that extended beyond peer-to-peer interaction to include project staff, STEM professionals and youth participants (Stylinski et al. 2012). Overall, treating teachers as knowledgeable team members allowed projects to focus their training and support on improving teachers' confidence and experience with the targeted complex and novel real-world technology applications.

Collaboration can be enhanced by collective participation with teachers working closely with others from the same school or district or even discipline; this can initiate communities of practices and improve the chance of implementation (e.g., Penuel et al 2007). Several ITEST projects included this strategy in their design by requiring teachers to apply as teams with others from their school or even their community. By contrast, many other project leaders had to recruit broadly to fill their demanding professional development offerings or did so because they wanted broad recruitment to ensure the real-world technology applications were infused across a mix of school courses.

Broader recruitment results in a larger diversity of teacher needs, and it is one reason many projects noted differentiated instruction was critical of their professional development design. To meet this need, project leaders often exploited technology, especially online resources, to provide individualized support; some helped with classroom implementation by assisting with technology use and student assessment. While costly, intense customized in-classroom support can dramatically improve implementation with the targeted technology (Varma et al. 2008).

Proximity-to-practice ensures professional development is directly translatable to the classroom and can include a focus on particular curricular materials (e.g., Penuel et al. 2007). Such alignment was quite important to the ITEST projects, as teachers needed guidance on implementing novel technology applications and related authentic STEM practices into their traditional classrooms. Thus, many project leaders sought strong connections between professional development and classroom activities, and all had teachers either developing their own technology-based curricular materials or adapted provided materials during the training (Stylinski et al. 2011). However, some incorporated projects activities that were quite distal with respect to the classroom; these involved fully immersing teacher in science research, engineering design and other real-world STEM practices to deepen teachers' understanding of these professional practices.

Some of the strategies described here are well represented in the literature on effective professional development practices. These include collaboration, proximity-to-practice, differentiated instruction, a focus on STEM content knowledge, and collective participation (Desimone et al., 2002; Garet et al., 2001; Loucks-Horsley et al., 2003; Penuel et al., 2007). Although not addressed in the interview, two other frequently cited strategies—extend duration and alignment with education standards—were also found in all ITEST projects as they were required by the NSF ITEST grant program. Likewise relevant to the ITEST projects was active learning, which is defined as opportunities to observe and be observed; to make classroom implementation plans; to review student work; and to participate in discussion on teaching (e.g., Garet et al. 2011, Penuel et al. 2007). Project leaders provided clear evidence of active learning in their design by focusing on inquiry and problem-/project-based learning, involving teachers in developing and adapting curricular materials, giving them an opportunity to try out pedagogical skills and materials during the out-of-school youth institute, and allowing time for discussion and reflect on their teaching and learning.

The technology-intensive ITEST projects also included strategies that are either not commonly cited in the literature or not emphasized in more traditional efforts. These included treating teachers as pedagogical and content experts and promoting deep collaborations among teachers and project staff. While peer-to-peer teacher collaborations have been shown enhance professional development and promote classroom implements (e.g., Desimone 2002), the benefits of teachers as equal team members, especially in technology-intensive training experiences, is not well understood.

Focusing on a pedagogical approach is also not as common in teacher education literature, especially those that align strongly with real-world STEM practices. Related studies on immersing teachers in science through internships have shown positive impacts on participants' identify, self-efficacy, confidence, knowledge, interest, and motivation to be science and math teachers (e.g., Baker and Keller 2010, Varelas et al. 2005), as well as improvements in student science achievement of participating teachers (Silverstein et al. 2009).

Finally, out-of-school experiences were integrated into all the ITEST projects, and many project leaders identified these as a critical component of the professional development. As described in our earlier paper, project leaders reported that these experiences afforded opportunities for teachers to practice-teach, try new approaches, reflect on their teaching, develop a deeper understanding of STEM practices and students' relationship with technology, and gain confidence for subsequent classroom implementation (Stylinski et al. 2012). Others have identified similar benefits of these low-stake settings (Saxman et al. 2010, Luehmann 2007), however the integration of informal education experiences into classroom teachers' professional development is not common.

Overall, more research is needed to understand effective strategies that help classroom teachers integrate real-world technology applications into their curriculum. This includes exploring benefits of engaging teachers as knowledgeable team members and focusing on pedagogical approaches that align with real-world STEM practices. We need to address the challenge of integrating these authentic practices within teacher professional development while maintaining strong alignment to classroom activities. We also need to better understanding how technology can be used to support differentiated instruction and how out-of-school experiences can help teachers develop skills and confidence to use sophisticated technology applications in their classrooms. We are continuing to explore these questions in our larger study as we examine teachers' attitudes about their professional development experiences and their subsequent classroom implementations.

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